RPS

4.0 Presentation

4.1 Introduction

4.1.1 RPS purpose

fission product barrier protection (AOO)

4.1.2 Anticipated Operational Occurrence (AOO)

10 CFR 50 appendix A
events expected to occur during design lifetime (40 years)

4.1.3 Limitations on plant operations (Safety Limits)

RPS ensures these limits NOT exceeded:

RCS pressure ... pressure boundary integrity

LHR ... fuel melt

DNBR ... clad integrity

4.1.4 Parameters limited:

since LHR and DNBR not readily measured:

reactor power
axial power imbalance
RCS pressure
RCS temperature
RCS flow

4.2 General System Description

4.2.1 Inputs:

neutron power
Th
RCS pressure
reactor coolant flow
RCP status
main turbine status
main feedwater pump(s) status

4.2.2 Logic

2/4 redundant channels sensing ANY trip condition will de-energize the control rods

4.2.3 205 differences

(1) photo-optical isolation

vice isolation amplifiers

separate non 1E signal from 1E

(2) solid state devices

vice relays

. faster response time
. more immune to seismic activity
. eliminates relays moving parts

(3) digital calculating module

replaced following trips:

power / flow / imbalance
power / pump
variable low pressure

with these trips:

DNBR
pump status
offset

4.3 Reactor trips (table 13.1)

4.3.1 High reactor power (105.5%)

prevent core damage during RAPID reactivity additions (press or temp too slow)

rod ejection
multiple rod group withdrawal
steamline break (EOL)

establishes an upper limit on power used in delta flux and DNBR considerations

4.3.2 ϕ / $\Delta\phi$ / flow (figure 13.1-1)

prevent exceeding Kw/ft and DNBR limits

high power trip with its setpoint reduced by RCS flow and/or flux imbalance (top - bottom)

outside the envelope ... reactor trip

replaced with DNBR and OFFSET trips in 205 FA

4.3.3 Power to pumps

prevent DNBR < 1.3

reactor trip if pumping power is lost
limits power production
prevents single loop operation

Pump combo	Trip setpoint
2/2	NA (> 125%)*
2/1	NA (> 125%)*
1/1	55%
0/1	Automatic trip
0/0	Automatic trip

* protection by ϕ / $\Delta\phi$ / flow trip

4.3.4 High T_h (644F)

limit provides protection range for DNBR

provides backup for:

overpower
high RCS pressure

4.3.5 High RCS pressure (2370 psig)

ensure safety limit NOT exceeded
(pressure boundary protection)

protection for SLOW reactivity additions:

- single rod withdrawal
- boron dilution accident
- undercooling (overheating) events

provides upper pressure boundary for DNBR calculations

4.3.6 Low RCS pressure (2000 psig)

prevent DNB

mitigate pressure decreasing transients:

- SGTR
- steamline breaks
- LOCA

setpoint such that:

- will NOT generate unnecessary trips during normal operations
- provides a minimum margin above ESFAS setpoint (1600 psig) to provide ESFAS bypass in a controlled cooldown

4.3.7 Variable low RCS pressure (figure 13.1-2)

DNBR protection under conditions not covered by low RCS pressure or high T_h trips

4.3.8 High reactor building (RB) pressure (4 psig)

ensure reactor shutdown during LOCA

4.3.9 Loss of main feedwater

ensure ability to remove reactor heat

TMI-2 modification

before TMI-2 ... high RCS pressure trip only provided loss of heat sink protection (reactor trip)

4.3.10 Reactor trip on turbine trip

shutdown reactor when heat sink (turbine lost)

TMI-2 modification

4.3.11 Manual

allow operator option to trip reactor if an "unsafe" condition exists

4.4 Reactor Trip Circuitry

4.4.1 Excore power range (figure 13.1-3)

2 detectors input to linear amp.

linear amp supplies:

summing amp (total power)
difference amp (imbalance)

function generator ... combines total and imbalance signal with RCS flow

4.4.2 Temperature (figure 13.1-4)

T_h RTD (one per channel)

RTD resistance converted to voltage signal (proportional to temperature change)

4.4.3 RCS pressure (figure 13.1-4)

4 pressure transmitters

2 per each hot leg

buffer amp receives, amplifies, and converts:

4 - 20 ma
to
0 - 10 vdc

1500 - 2500 psig

bistables actuated:

high pressure trip
low pressure trip
shutdown bypass trip
variable low pressure trip

4.4.4 Reactor building pressure

pressure transmitter (or switch) inputs to bistable

comparison to setpoint (4 psig)

4.4.5 Anticipatory trip circuit (figure 13.1-5)

contact inputs ... in series with channel trip relay

parallel contacts (power) bypass trips 'til power above setpoint (40%) ... allows plant startup

4.4.6 RCS flow

2 flow transmitters in each hot leg

summed for total flow

supplied to ϕ / $\Delta\phi$ / flow trip

4.5 RPS Channel Logic (figure 13.1-6)

4.5.1 Normal condition (no trip signals present)

all contacts closed

channel trip relays energized

4.5.2 One channel trip signal present

channel A ... example

ANY trip parameter (channel A) exceeds it's setpoint ... opens associated contacts ... de-energizes channel trip relay (KA)

4 output logic relays (KA1, KA2, KA3, and KA4) de-energize ... each informing it's associated RPS channel that channel A has tripped

KA1 contacts in UV coil circuitry open

UV coils remain energized through closed contacts (KB1, KC1, and KD1)

Note: reactor has NOT tripped

4.5.3 Channel trip reset

KA contact (parallel with channel reset switch) was opened on trip signal ... seals trip signal in on channel A ... trip condition must be cleared and reset switch depressed to re-energize channel trip relay

4.5.4 2 separate RPS channels tripped

power interruption to UV coils

trip breakers open

control rods fall into core

KEY POINTS:

(1) minimum of 2/4 channels for reactor trip (logic satisfied by 8 series/parallel contacts in UV coil circuitry)

(2) coincidence trip logic does NOT exist ... 2 unrelated channel trips WILL cause reactor trip

4.6 Reactor Trip Circuit Breaker Logic

4.6.1 177 FA System (figure 13.1-7)

separate power sources through AC circuit breakers (A and B)

UV coils for A & B powered from RPS channels A & B

voltage regulators and stepdown transformers supply:

(1) redundant DC busses

A phase supply
CC phase supply

either phase sufficient to hold safety rods (full out)

2 breakers on output of each power supply ... each breaker supplies 2 of 4 safety groups

2 UV coils from RPS C

2 UV coils from RPS D

(2) regulating (and auxiliary) rod power supplies

SCRs gated on by programming lamps

programming lamp power controlled by RPS C & D

AC breaker and (2) DC breaker(s) are in series (treat DC as one breaker)

redundant arrangement of supplies calls for: 1x2x2 logic for trip

Examples (page 13.1-7)

4.6.2 205 FA System (figure 13.1-8)

also Davis-Besse

2 separate power sources ... each with full power capability

2 series circuit breakers in each supply

RPS channel feed UV coil of 1 breaker

1x2x2 logic ... allows testing and still meet single failure criteria

4.7 System Testing

4.7.1 Introduction

analog trips

- pressure
- temperature
- power
- pump status (contact inputs)

installed test power supply substituted for detector output

verify buffer amp and bistable trip units

if in channel bypass ... test module can be operated without causing channel trip (figure 13.1-6)

each channel supplied from different vital bus

all trip devices de-energize to initiate trip

example ... removal of trip bistable ... opens associated channel control rod breaker

4.7.2 Module interlocks and test trip relay (figure 13.1-6)

identified on channel D

module in test mode ... test trip relay opens TT contact ... indicates channel trip

normally channel placed in bypass BEFORE module is tested

2/4 RPS logic permits channel testing on-line without initiating a reactor trip

4.7.3 Bistable modules (figure 13.1-9)

converts analog input to digital output when setpoint is reached (increasing or decreasing)

adjustable deadband ... ensures positive switching action at setpoint

memory circuit ... reset manually ... indicates bistable state (lights)

dim ... power avail ... non-tripped

bright ... bistable tripped

toggle switches reset bistable state & memory

adjustments:

setpoint
deadband

test jacks measure voltage:

input
setpoint
deadband

4.7.4 Bistable test

insert analog input from channel test module (figure 13.1-10)

vary input 'til bistable setpoint reached

true value of bistable setpoint measured by:

analog indicator of test signal
digital voltmeter

bistable operation observed by trip status light in reactor trip module (figure ~~13.1-11~~ 10.1-10)

4.7.5 RPS logic & CRD breaker logic test

pressing various combinations of two logic test switches ... simulate 6 combinations of trips (2/4 logic)

observe (reactor trip module):

trip logic relay lights
breaker trip lights

4.7.6 Channel bypass (figure 13.1-6)

allows maintenance and testing (key switch)

keeps channel trip relay energized while testing bistable relays

1 RPS channel at a time!

ensured by series contacts

any contact opened ... second channel cannot be bypassed

bypass relay energized ... RPS logic reduced to 2/3

4.7.7 Shutdown bypass

allows safety rods out during cooldown ...
bypass low pressure trip

trip would occur when pressure < 2000 psig

procedure:

insert rods prior to 2000 psig
decrease pressure < 1820 psig
RPS channels to shutdown bypass
withdraw safety rods

trips bypassed:

low RCS pressure
ϕ / $\Delta\phi$ / flow
power / pump
variable low pressure

inserts high pressure trip setpoint (1820 psig)

prevents operation at normal pressure with part of RPS bypassed

high flux trip setpoint is reduced to 5%

backup for high pressure trip
admin. controlled

4.8 PRA Insights

4.8.1 ATWS sequence

(1) valid trip signal with double failure of reactor trip circuit breakers

(2) main feed pumps trip or runback

(3) operator fails to initiate feed and bleed core cooling

4.8.2 ANO-1 PRA values

core melt frequency contribution .. 6%

RPS risk reduction factor 1.06

RPS risk achievement factor 56,001

large value due to small RPS failure probability in the analysis

NOTE: PRA study completed before shunt trip addition was required

4.8.3 Shunt trip requirements (figure 13.1-12)

Generic letter 83-28

auto actuation of shunt trip on CRD breakers

1 relay for each RPS channel provides power to shunt trip

connected in parallel with the UV coil on CRD breaker

control power through contacts actuated by shunt relay

de-energize UV and / or shunt relays:

trips CRD breaker

4.8.4 Backup scram system (figure 13.1-13)

minimize probability of ATWS event by reducing likelihood of trip system failure

10 CFR 50.62

(1) auto activate aux feed and turbine trip

(2) additional scram system independent of reactor trip system

2 channels of instrumentation

RCS pressure input to bistable

setpoint ... 2450 psig

contact closes ... energizing BSS relays ... opens programming lamp circuits ... degating 1 group of SCRs

2nd channel actuation ... degates 2nd group of SCRs ... removing CRDM power ... rods fall

2/2 channels for actuation

5.0 Slides